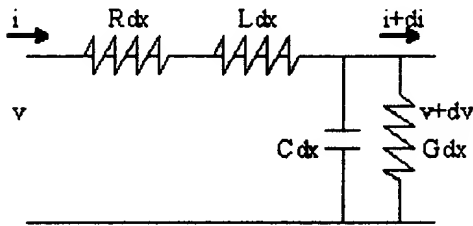


Next: Summary of properties for the coaxial line

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II. The model for studying the coaxial cable transmission line

The significant circuit parameters for a transmission line are shown below



R , L are the series resistance and inductance per length. C , G are the shunt capacitance and conductance per length.

We can get the fundamental equations of transmission line theory,

$$-\frac{\partial v}{\partial z} = Ri + L \frac{\partial i}{\partial t} ; \quad -\frac{\partial i}{\partial z} = Gv + C \frac{\partial v}{\partial t}$$

Such kind of linear differential equations can be solved by means of Laplace transforms.

First, do the Laplace transform on both sides of each differential equation,

$$-\frac{\partial \tilde{v}}{\partial z} = R\tilde{i} + Ls\tilde{i} - Li_{z=0} ; \quad -\frac{\partial \tilde{i}}{\partial z} = G\tilde{v} + Cs\tilde{v} - Cv_{z=0}$$

Second, solve these two coupled equations, do the second derivative with respect to z (the propagation direction) and substitute original equations into them, we get

$$\frac{\partial^2 \tilde{v}}{\partial z^2} = (R + Ls)(G + Cs)\tilde{v} ; \quad \frac{\partial^2 \tilde{i}}{\partial z^2} = (R + Ls)(G + Cs)\tilde{i}$$

the solutions are

$$\tilde{V} = A_1 e^{-\sqrt{(R+Ls)(G+Cs)}z} + B_1 e^{\sqrt{(R+Ls)(G+Cs)}z} ; \quad \tilde{I} = A_2 e^{-\sqrt{(R+Ls)(G+Cs)}z} + B_2 e^{\sqrt{(R+Ls)(G+Cs)}z}$$

we can define $\gamma = \sqrt{(R+Ls)(G+Cs)}$, which is just so called the propagation constant of the line.

Considering the practical physical meaning,

$$B_1 = 0 ; \quad A_1 = \tilde{V}(z=0, s) = \mathcal{L}(v(z=0, t)) = \mathcal{L}(v_0(t)) = \tilde{V}_0(s)$$

$$B_2 = 0 ; \quad A_2 = \tilde{I}(z=0, s) = \mathcal{L}(i(z=0, t)) = \mathcal{L}(i_0(t)) = \tilde{I}_0(s)$$

where $\tilde{V}_0(s)$ $\tilde{I}_0(s)$ are just the Laplace transform of the initial signal at the origin. The transfer function is defined as $H(j\omega) = H(s) = e^{-\gamma z} = e^{-\sqrt{(R+Ls)(G+Cs)}z}$

From the relation of $\tilde{V}_0(s)$ and $\tilde{I}_0(s)$, we have $\frac{\tilde{V}}{\tilde{I}} = \frac{\tilde{V}_0}{\tilde{I}_0} = \sqrt{\frac{R+Ls}{G+Cs}} = Z_0$

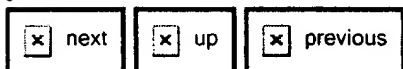
this quantity is called the surge impedance of the transmission (or the characteristic impedance) of the transmission line.

Finally, find the inverse transform

$$v(z, t) = \mathcal{L}^{-1}(\tilde{V}_0(s) e^{-\sqrt{(R+Ls)(G+Cs)}z}) ; \quad i(z, t) = \mathcal{L}^{-1}(\tilde{I}_0(s) e^{-\sqrt{(R+Ls)(G+Cs)}z})$$

we obtain the wave form function in our familiar space-time frame.

In general case, signals propagate in a transmission line with distortion due to the limitation of bandwidth and the certain change of the spectrum the signals by the transmission line. Although the distortionless case maybe of specific interest, here I just concentrate on the more common phenomenon--distortion., which is taking place on most signal transmission.



Next: Summary of properties for the coaxial line

Derek Yong Qin (e-mail: yqin@wpi.edu)

Last modified: Feb.21, 97



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Aston University**Department of Electronic Engineering and Applied Physics****HSPICE User Guide: Transmission Lines Supplement**

INTRODUCTION

This document should be read in conjunction with the 'HSPICE User Guide'. It covers additional information required to model and simulate transmission lines with HSPICE.

A transmission line is a device intended to deliver an output signal at a distance from the point of signal input. Transmission lines include power cables, telephone lines, and waveguides. Less obviously perhaps, printed circuit boards, multi-chip modules and even integrated circuit packages have to be considered as transmission lines when operating frequencies are high.

The extra effects which are introduced by transmission line models are: time delay, phase shift, power loss, distortion and reduction of bandwidth.

HSPICE provides facilities for modelling lossless (ideal) and lossy transmission lines.

It also provides facilities to model numerous different physical layouts of the conductors forming the transmission lines. In this document only coaxial cables and twin-lead cables are described. Full details are in the Meta-Software HSPICE manual. See Mr. Wilton if you wish to consult that manual.

This document is also available in PostScript format on the Aston University WWW server. (URL <http://www.eeap.aston.ac.uk/eeap/documents/user-guides.html>).

HSPICE TRANSMISSION LINE ELEMENTS

There are two transmission line elements. The T element is used for ideal transmission lines and the U element for lossy transmission lines. In addition the U model may be used to combine ideal and lossy elements. However, it is often convenient (and more consistent) to use the U model with the relevant parameters even for ideal lines.

The ideal line is modelled as a voltage source and a resistor. The lossy line is modelled as a multiple lumped filter section.

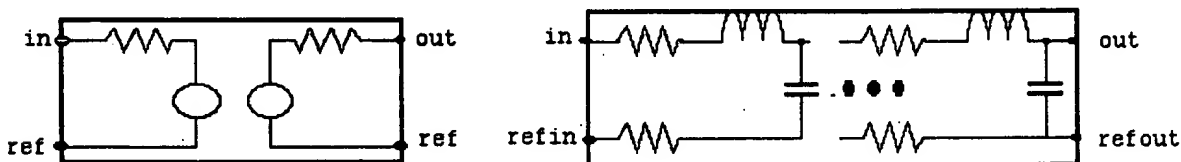


Fig 1. Ideal and lossy transmission line models

LOSSLESS TRANSMISSION LINE (T ELEMENT)

Syntax

Txxx in refin out refout <mname> z0=val td=val L=val

in Signal node (in side)

refin Ground reference for input.

out Signal node (out side)

refout Ground reference for output.

mname U model reference name

z0 Characteristic impedance

td Transmission delay (secs/m)

L Physical length of the transmission line in metres. The default value is 1m.

LOSSY TRANSMISSION LINE (U ELEMENT)**Syntax**

For 1 wire and ground plane

Uxxx in refin out refout mname L=val

For 2 wires without ground plane (unshielded twin)

Uxxx in1 in2 out1 out2 mname L=val

For 2 wires and ground plane

Uxxx in1 in2 refin out1 out2 refout mname L=val

in, in1, in2 Signal node(s) (in side)

refin Ground reference for input.

out, out1, out2 Signal node(s) (out side)

refout Ground reference for output.

mname U model reference name

L Physical length of the transmission line in metres. The default value is 1m.

TRANSMISSION LINE MODEL (U MODEL)

The U model is intended for specifying the extra parameters for lossy lines but it is convenient to use it also to specify the parameters required for lossless lines.

The syntax is:

```
.MODEL mname U LEVEL=3 PLEV=x ELEV=x <DLEV=x>
```

```
+ <Pname=val> ...
```

mname **Model name.**

PLEV Physical level. Used to distinguish between planar conductors (PLEV=1), Coaxial conductors (PLEV=2), Twin and twisted pair conductors (PLEV=3)

ELEV Electrical level. Used to distinguish modelling via geometry such as thickness, width, dielectric (ELEV=1), pre-calculated equivalent resistance, capacitance and inductance (ELEV=2), measured impedance and delay (ELEV=3).

DLEV Device level. A further level of refinement for different conductor/dielectric configurations.

In this document only geometric and measured parameter modelling are considered.

GEOMETRIC MODELLING (ELEV=1)

Coaxial cable

Geometric coaxial cable modelling is selected with U model parameters PLEV=2, ELEV=1. the DLEV parameter is not required.

```
.MODEL mname U LEVEL=3 PLEV=2 ELEV=1 <Pname=val> ...
```

The physical geometry parameters for coaxial cable are shown in Fig. 2 and described in Table 1.

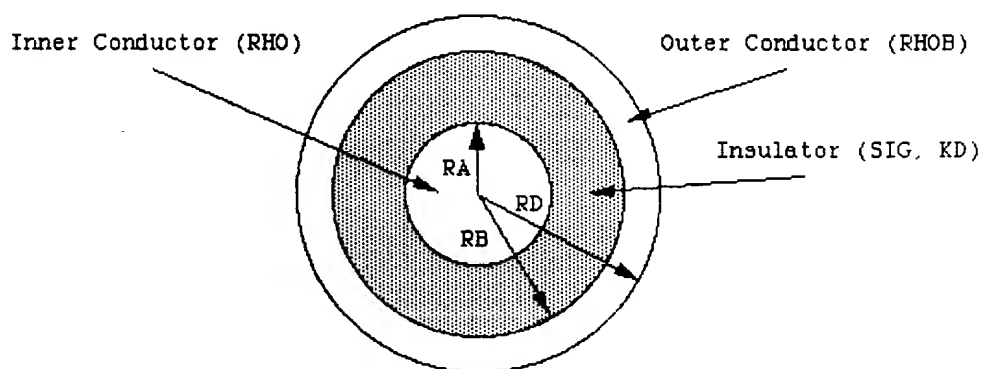


Fig. 2. Coaxial Cable geometry

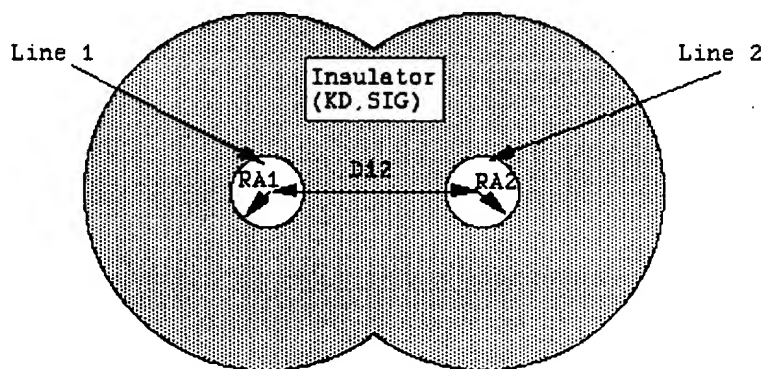
Name	Unit	Default	Description
RA	m	required	Outer radius of inner conductor
RB	m	required	Inner radius of outer conductor (shield)
RD	m	RA+RB	Outer radius of outer conductor (shield)

HGP	m	1.5.RD	Radius to circuit ground point
RHO	[[Omega]]m	17E-9	Resistivity of conductor material (default=Copper)
RHOB	[[Omega]]m	RHO	Resistivity of shield material
SIG	[[Omega]]-1m-1	0.0	Conductivity of dielectric
KD		4.0	Relative dielectric constant

Table 1. Geometric Coaxial cable parameters**Twinlead cable**

Geometric twinlead cable modelling is selected with U model parameters PLEV=3, ELEV=1. Differences caused by the presence of a shield are indicated by a third parameter DLEV. The different geometric parameters are shown in Fig 3a (sea of dielectric), Fig. 3b (insulating spacer) and Fig. 3c (shielded). The parameters are described in Table 2.

Name	Unit	Default	Description
DLEV		0	Device Level.
RA1	m	required	Outer radius of conductor 1
RA2	m	RA1	Outer radius of conductor 2
D12	m	required	Distance between conductor centres
RHO	[[Omega]]m	17E-9	Resistivity of conductor material (default=Copper)
KD		4.0	Relative dielectric constant
SIG	[[Omega]]-1m-1	0.0	Conductivity of dielectric
HGP	m	1.5.D12	Radius to circuit ground point
RHOB	[[Omega]]m	RHO	Resistivity of shield (if present)
OD1	m	required	Maximum outer dimension of shield (if present)
OD2	m	OD1	Minimum outer dimension of shield (if present)

Table 2. TwinLead cable parameters**Fig. 3a. TwinLead cable (sea of dielectric) geometry**

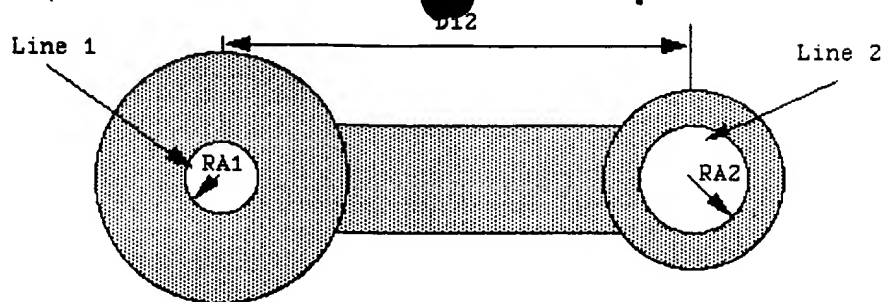


Fig. 3b. TwinLead cable (insulating spacer) geometry

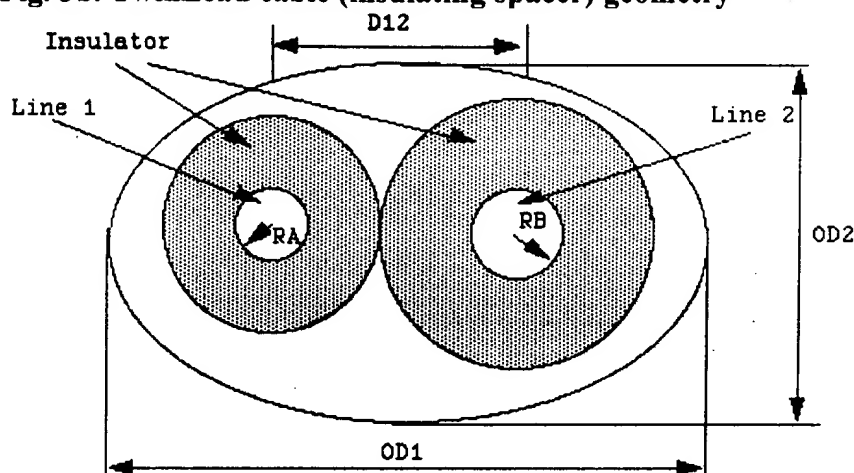


Fig. 3c. TwinLead cable (with shield) geometry

PRE-COMPUTED ELEMENT MODELLING (ELEV=2)

Not covered in this document.

MEASURED ELEMENT MODELLING (ELEV=3)

When measured parameters are given, HSPICE calculates the resistance, capacitance and inductance parameters using TEM transmission line theory. If some parameters are redundant HSPICE guesses which are most likely to be accurate and discards the others.

This modelling method is most useful for standard cable types where the parameters can be extracted from tables.

Name	Unit	Default	Description
ZK	[$[\Omega]$]	calculated	Characteristic impedance
VREL		calculated	Relative velocity of propagation
DELAY	sm-1	calculated	Delay/length
CAPL	Fm-1	1.0	Capacitance/length
AT1	m-1	1.0	Attenuation factor/length

Table 3. Measured parameters

The measured parameters for some standard cables are given below.

Coaxial cable type RG58 (Thin Ethernet)

```
.model rg58c u level=3 plev=2 elev=3 zk=50 capl=100.7p  
+ vrel=0.66 frl=100meg atl=0.173db
```

Twisted pair (Shielded)

```
.model tw/sh u level=3 plev=3 elev=3 zk=300 capl=25.5p  
+ vrel=.698 frl=57meg atl=0.0566db
```

Twisted Pair (Unshielded)

```
.model tw/un u level=3 plev=3 elev=3 zk=300 capl=17.3p  
+ vrel=.733 frl=100meg atl=0.0458db
```

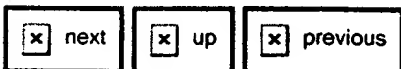
OTHER TRANSMISSION LINE PARAMETERS

There are a few U model parameters which may be used irrespective of the type of transmission line. These are used to control the simulation algorithms.

WLUMP=val Number of lumps per wavelength for error control. The default value is 20.

MAXL=val Maximum number of lumps per element. The default value is 20.

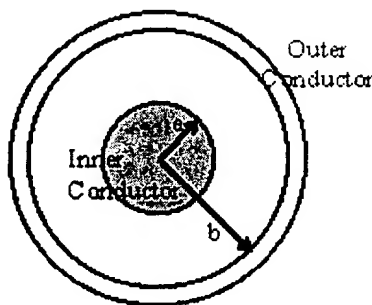
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Next: Properties of coaxial cable RG-58 A/U

III. Summary of properties for the coaxial line

Cross section of coaxial cable,



Basic formula[1]:

$$\text{skin depth } \delta = \sqrt{\frac{2}{2\pi f \mu \sigma}}$$

the series resistance R (the skin effect impedance R_s) per length

$$R = \frac{1}{2\pi} \left(\frac{1}{a} + \frac{1}{b} \right) R_s, \quad \Omega/m; \quad R_s = \sqrt{j2\pi f \frac{\mu}{\sigma}} \quad \Omega/m^2$$

$$\text{series inductance per length } L = \frac{\mu}{2\pi} \ln\left(\frac{b}{a}\right) \quad H/m$$

$$\text{the shunt capacitance per length } C = \frac{2\pi \epsilon}{\ln\left(\frac{b}{a}\right)} \quad F/m$$

$$\text{the shunt conductance per length } G = \frac{2\pi \sigma}{\ln\left(\frac{b}{a}\right)} \quad 1/(\Omega \cdot m)$$

next up previous

Next: Properties of coaxial cable RG-58 A/U

Derek Yong Qin (e-mail: yqin@wpi.edu)

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spreader a device that spreads; specific uses include: *Civil Engineering*. 1. any appliance that distributes water uniformly in or from a channel. any appliance that distributes water uniformly in or from a channel. 2. a machine fitted with wide plates for spreading soil, subsoil, or rock excavated from a pond, drainage ditch, or other cut. a machine fitted with wide plates for spreading soil, subsoil, or rock excavated from a pond, drainage ditch, or other cut. *Mining Engineering*. 1. a timber placed horizontally below the cap of a set to stiffen the legs and support the brattice when two air courses are in the same gangway. a timber placed horizontally below the cap of a set to stiffen the legs and support the brattice when two air courses are in the same gangway. 2. a piece of timber set across a shaft for temporary wall support. a piece of timber set across a shaft for temporary wall support. *Electricity*. an insulator used to separate the wires of an air terminal. *Mechanical Engineering*. a tool used in sharpening machine drill bits.

Previous Words

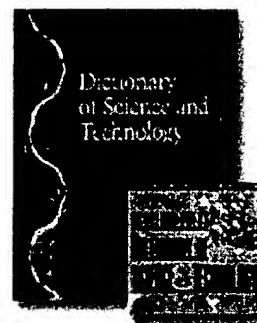
[spray torch](#) [spray tower](#) [spray transfer](#) [spray-up](#) [spread](#)

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Microstrip

... constant for the waves on the **transmission line** will lie somewhere between that of ... As an example, in (notionally) **air spaced** microstrip the velocity of waves ...
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Transmission lines

... the wicking of water up the **semi-air-spaced** dielectric separating inner conductor from sheath. ... **Transmission line** with exposed conductor surfaces can experience ...
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Sage Components

... at lower frequencies where **transmission line** devices might be excessively large. ... High Q porcelain chip-capacitors and **air-spaced** inductive coils are soldered ...
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... of **transmission line** acts as a small tuned circuit, with inductance from the two conductors and capacitance from capacity between the conductors. **Air spaced** ...
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TDR LL 4

... We fabricated an **air-spaced** coaxial **transmission line** using accessible materials to achieve a reasonable impedance match to standard RG58U (53W) coax cable. ...
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wire dictionary

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... control station; air sounding; **air-spaced** coaxial cable; air terminal; AIS; ... artifact; artificial intelligence (AI); artificial **transmission line**; art line; ARU; ASCII; ...
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Harcourt: AP Dictionary of Science and Technology:

... shaft for temporary wall support. Electricity, an insulator used to separate the wires of an **air-spaced transmission line**. Mechanical Engineering, a tool used ...
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Some J-Poles That I Have Known

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PDF cable for American Standards Association. Former name of ANSI. 32...File Format: PDF/Adobe Acrobat - [View as HTML](#)

... in a ci ease rcuit. with **Air Spaced** Coaxial Cable One in which air is ... connected to the output terminals of a **transmission line** of any length, makes the line ...
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Rapicom, Inc. **1-888-367-3423** Glossary of Technical Terms

... **Air Spaced** Coaxial Cable - One in which air is the essential ... when connected to the output terminals of a **transmission line** of any length, makes the line appear ...
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... This does not appear to be significant but is a problem for UHF **transmission line** cables. Hence, **air spaced** coaxial cables are used for TV aerial leads. ...

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... closed ring of magnetic material; windings are **air-spaced**; windings are wound on a ferrite rod; inductor ... the transmitter used; the length of the **transmission line**. ...

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Radio Computer Programs

... which would occur on a long **transmission line** of impedance R_0 if such a line ... father (who made his own variable, **air-spaced** tuning condensers) with threats of ...

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... compact alternative to other forms of **transmission line**, and is used to make devices such ... in the use of ultra-large, **air-spaced** microstrip lines to provide a ...

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Madison Glossary

... **Air Spaced Coaxial Cable**--One in which air is the essential ... of voltage to current at any point along a **transmission line** on which there are no standing waves. ...

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Re: Characteristic Impedance

... resistance R per unit length of the coaxial **transmission line** in terms of the outer conductor radius b ... For **air-spaced** coaxial line the ratio of 3.6 corresponds ...

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Patent Specification No. 466,418

... proceed as follows:-. A **transmission line** comprises a conductor enclosed within a sheath to form a concentric cable and substantially **air spaced** from the sheath ...

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... inner and outer conductors of an **air-spaced** coaxial **transmission line** at a point on the line. A low frequency signal is fed into one end of the line and the ...

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AM-6154/6155 FAA Surplus Amplifiers

... actually an air-insulated coaxial **transmission line** with an adjustable shorting plate ... conductor is connected to an **air-spaced** variable capacitor mounted within ...

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AAR. American Association of Railroads Abrasion Resistance...

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... Quarterwave Plate Polarizer = Glan-Air Spaced Calcite Polarizer Figure 4. Pulsed ... Configuration

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... to the modulator under test was established via an **air spaced** 50 Ω coplanar probe and the **transmission line** was terminated with a 35 Ω resistance on the chip ...

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Lens Recoating

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